A DESKTOP COMPUTER SOFTWARE PACKAGE FOR DISPLAY AND ANALYSIS OF MULTIDIMENSIONAL MEDICAL IMAGES

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ABSTRACT

A three-dimensional, multiple volume image analysis package is described for use with the OS/2-Presentation Manager operating environment for 80286 and 80386 based personal computers. The package allows the user to manipulate, display, and measure volumetric data using several different techniques. Multiple windows allow correlated views or calculations to be performed simultaneously on different volumes. Highly optimized code provides satisfactory performance on desktop computers.

BACKGROUND

Two-, three-, and four-dimensional (2D, 3D, 4D) medical images are routinely acquired and analyzed in both clinical and research environments. These may have been generated using X-rays, ultrasound, magnetic resonance, positron emission, light, or some other imaging technique. Regardless of the dimensionality of the data, analysis is usually performed on 2D images.

Many software packages--from both commercial and research institutions--have been developed for performing 3D display and analysis. Several different paradigms for representing the volumetric data have been developed in these packages including conventional polygons [1], cuberille models [2], contours [3], and octrees [4]. A method which has become popular recently is ray-casting or volume rendering [5].

The Biodynamics Research Unit at the Mayo Clinic has been actively involved in the analysis of 3D and 4D images since the development of the Dynamic Spatial Reconstructor [6] in the 1970s. A number of software 'tools' have been developed over this time and combined into a comprehensive package called ANALYZE [7,8]. Some of the display tools in this package include oblique sectioning, shaded surface displays, and volume renderings. In addition, the software package allows the user to mathematically manipulate the volume--resizing, subregioning, rotation, and windowing of volume data sets. Several types of quantitative measurements, both regional and global, may also be made on the data set.

ANALYZE runs on UNIX-based 32-bit workstations. However, one of the most popular and ubiquitous computers is the IBM PC/AT family and compatibles (hereafter referred to as PCs) running Microsoft DOS. Therefore, a display and analysis package for medical imaging based on the PC would be desirable. This paper describes such a package developed in our laboratory.

SOFTWARE PARADIGM

It would seem reasonable that since ANALYZE runs under UNIX and because UNIX is available for the PC, a simple port of ANALYZE could have been done. This proved to be difficult because of the idiosyncrasies of the version of UNIX which was available and because of the 80286's 16-bit architecture. A version for DOS with bank-switching schemes was also attempted but proved to be slow. When Microsoft Corporation (Redmond, WA) announced the availability of the OS/2 operating system and Presentation Manager (OS/2-PM) environment, which maintained compatibility with DOS, supported a large memory, and offered an integrated windowing environment, development of an OS/2-PM image analysis package was begun.

It is generally accepted that intuitive, consistent user interfaces are important for operator efficiency. To this end, OS/2-PM provides tools for handling windows and dialogue boxes whose operation is consistent across all software packages.

Multiple windows have become popular because they allow interaction with multiple processes on one display screen. In addition, multiple window display formats may be useful for 3D and 4D image display and analysis because they allow the user to simultaneously interact with the same data set displayed with different techniques, or different but related data sets using the same technique, as well as simultaneously performing unrelated tasks.

Therefore, another design consideration arose--allowing more than one active data set. This increases the demand for memory, but significantly increases functionality. Multiple display methods and/or multiple data sets necessitate a data structure for computing correlated images between windows.

This structure is a matrix of values which describes the rotation, translation and scaling of the volume. When so

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indicated, (by setting the 'Send' checkbox) the matrix is sent to all windows set to 'Receive' the message. These windows take the matrix and generate the appropriate image.

Although the computing power of PCs has increased dramatically, the majority of PCs are still much slower than the typical UNIX workstation. To achieve reasonable response time on interactive tasks, highly optimized code was developed and has been described elsewhere [9,10]. Having the entire volume in CPU memory is important for increasing speed because random access to voxels is necessary for many of the display and analysis tasks. Although volume renderings and SSDs are not generated at interactive speeds, the time required is not unreasonable for most purposes (a few seconds). All other interactive tasks (oblique sectioning, manual segmentation, volume estimation) occur at interactive speeds.

Because the operating system requires window procedures to return control to the operating system within a small amount of time, all compute intensive procedures (volume render, SSD, filtering, etc) are written as separate threads which communicate with the window procedure via semaphores. This also provides clear demarcation of logical processes which may be assigned to separate processors in a multi-processor computer.

DISCUSSION

The analysis package allows the user to compute and display orthogonal, curved, and oblique sections. Volume renderings, shaded surface displays, and projection/dissolution sequences may also be computed and displayed. First-order statistics on regions or volumes of interest may be computed and written to a disk file. Segmentation may be performed using interactive thresholding, a variety of filters, and/or manual segmentation. Disk files may be manipulated to effect addition, subtraction, scaling, masking, subregioning, and resizing.

Currently, the major limitation of the package is posed by the operating system. Most images consist of at least 8 bits of gray-scale information. However, the current release of OS/2-PM for the PC family only supports EGA or VGA displays (640x350 or 640x480 pixels with 4 bits per pixel). Consequently, to view the full color scale of an image, it is necessary to use an auxiliary display card and monitor. As OS/2-PM matures and begins to support higher resolution cards (e.g., extended VGA at 800x600 8 bits/pixel or 8514/A at 1024x768, 8 bits/pixel) we intend to use just one display screen. Furthermore, this will allow the code to be more device independent because the task of converting a gray-scale image to the appropriate bit-plane format will be handled by OS/2-PM.

CONCLUSION

Desktop computers are viable platforms for productive, easy to use multi-dimensional medical image processing. A PC-based software package using the OS/2 and Presentation Manager environment has been implemented permitting multivolume, multiwindow display, manipulation and analysis to be performed.

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